Analysis of Lake Water Levels Fluctuations in Poland and Belarus

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ABSTRACT

On the basis of the mean volume of annual water levels for 25 lakes (9 Belarusian and 16 Polish) in the period of 55 years (1956-2010) the spectral time analysis of water levels fluctuations has been executed. The spectral time analysis included two parts: analysis based on calculating the variance specters in comprised time distances and analysis of similarity in spectral images of water levels. The first part of the research has shown that for Belarus the most often observed cycles were 3, 5 and 10 years cycles. The majority of Polish lakes have cycles of 5 and 10 years. The second part of the research allowed dividing lakes into three groups. The first group included 14 lakes distinguished by smooth curves with no significant peaks and is represented by the lakes of the central and northern part of Belarus and eastern part of Poland. The second group shows four-year variability and includes lakes of the eastern part of Belarus. The third group is distinguished by a peak of three-year water fluctuation and includes lakes of central and north Poland.

1. Introduction

Today, a lot of methods have been widely used to analyze and predict water resources, especially in lake level forecasting. Soil and Water Assessment Tool (SWAT) can simulate water, sediment, and nutrient yield in a watershed by using input data from GIS and applying different agricultural practices, climate change, and land use (Bosch et al., 2011; Makarewicz et al., 2014). Using of artificial intelligence methods in lake level forecasting is also used (Shaghaghi et al., 2017; Zeynoddin et al., 2018). Another method of lake level fluctuations analysis and prediction is long-term studies of ice phenology (Apsite et al., 2014; Kostecki, 2013).

The aim of the present study is to determine homogeneous hydrological regions of Belarus and Poland and to explain the regularity of the mean annual water levels in Belarusian and Polish lakes for future lake level forecasting.

2. Data sources and methodology

The research data included water levels (mean annual) of 25 lakes (9 Belarusian and 16 Polish) for 55 years of continuous observation period (1956-2010). The selection of lakes was based on two criteria: data continuity and lack of significant anthropogenic impact. The types of the lake basins are particularly post-glacial, but also coastal and marshy basins occur. In terms of character of water exchange, the lakes are weakly flow-through or outflow lakes, and in terms of trophic status – mesotrophic, eutrophic, and dystrophic.

The analysis of the cycle fluctuations of water levels of the Belarusian and Polish lakes has been executed with the use of the spectral-time analysis (STAN). The basis of the analysis is calculating the variance specters in comprised time distances (Loginov, Ikonnikov, 2003). The variance spectrum consists of a

number of harmonic components amplitudes. The frequencies of amplitudes are compiled on an ordinate axe of the STAN diagram whereas on the abscissa axe they correspond to one half of time window.

The methodology of grouping lakes was based on analyses of similarity of spectral images of water levels (Druzhinin, Sikan 1999; Volchak et al. 2017). The spectral density of the studied lakes was analyzed in time intervals and includes the smoothing function, for which the Nuttall window was adopted (Marple, 1987).

3. Results

The first part of the research was to analyze lake level fluctuations using STAN. It has shown that for all the investigated lakes there exist short-period cycles of 3, 5 and 10 years. For Belarusian lakes most cycles occurring simultaneously are 3, 5 and 10 years i.e. for Driviaty, Lukomskoe, Miastro, Nescherdo Lakes. For Senno Lake 3 and 5 years cycles have been separated, for Osveiskoe Lake 5 and 10 years cycles were identified. In the rest, however, having the largest areas (Vygonoschanskoe, Naroch, Chervonoe Lakes) only 10 years fluctuation cycle has been detected. For seven Polish lakes 10 years water fluctuation cycle has been defined and in the case of five lakes 5 and 10 years cycles were detected. Two lakes have 3 and 5 years cycles, for Sławskie Lake 3 and 10 years cycles were indicated and only for Lake Rajgrodzkie there was only one 5 years long cycle. The continental climate growing in eastern direction appears to be one of the key factors impacting the discovered regional fluctuations of water levels in lakes.

The second part of the presented research allowed dividing investigated lakes into three groups. The first group shows a smooth curve with no significant peaks. It was determined for the majority of the studied lakes. Four-year variability is characteristic for the water level spectrum of lakes of the eastern part of Belarus and Lake Studzieniczne. The third group includes the lakes of north-western Poland. This group of spectra presents a curve with a peak of a three-year water level fluctuation. The classification of lakes according to the analysis of similarity of images of water level spectrum density facilitated the assessment of the primary statistical parameters. Coefficients of variability and autocorrelation have the highest values for lakes from the second group. The ratio of the coefficients of asymmetry and variability has very evident tendencies to increase from the first to the third group.

4. Conclusion

The spectral analysis of water level fluctuations in the lakes using data for 25 lakes was performed. Most of the lakes have 3, 5 and 10 years cycles. Cycle fluctuations of the analyzed data have above regional character and the biggest impactful factor can be the continental climate. Regional factors can modify the pattern as well and also those of a small range of activity, mainly the local ones. The lakes dividing into groups detected 3 groups. The first includes 14 lakes. The second group includes five lakes. The third group is represented by six lakes. Presented results can be used as an initial data for level prediction for the Belarusian and Polish lakes.

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